FRACTAL ANTENNA™
SYSTEMS INC

Fractal Superscatterers for Small Satellite Identification

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4/24/2019

About Fractal Antenna Systems

- **Innovation, technology, and manufacturing company** – Dozens of 'source' patents across multiple domains, custom product development and manufacturing capabilities
- **Fundamental technology/IP on *Fractals* in:** Antennas, resonators, metamaterials, radiative transfer, absorbers, transformational optics, aperture engines, invisibility cloak and metasurface stealth, 3D printing, batteries, electromagnets, spacecraft
- **Customer list *(partial, direct or sub)* includes:** DARPA, JPL, Navy, Air Force, NAVEODTECH, NSA, TLA's, Marines, Raytheon, Lockheed Martin, Northrup Grumman, General Dynamics, Boeing, Sierra Nevada, BAE
- Since 2010, primary focus on **commercial markets** including: Wireless infrastructure (5G, DAS), Aerospace, Medical devices
- Design & manufacture **on-satellite antennas**, customers in the small sat mix

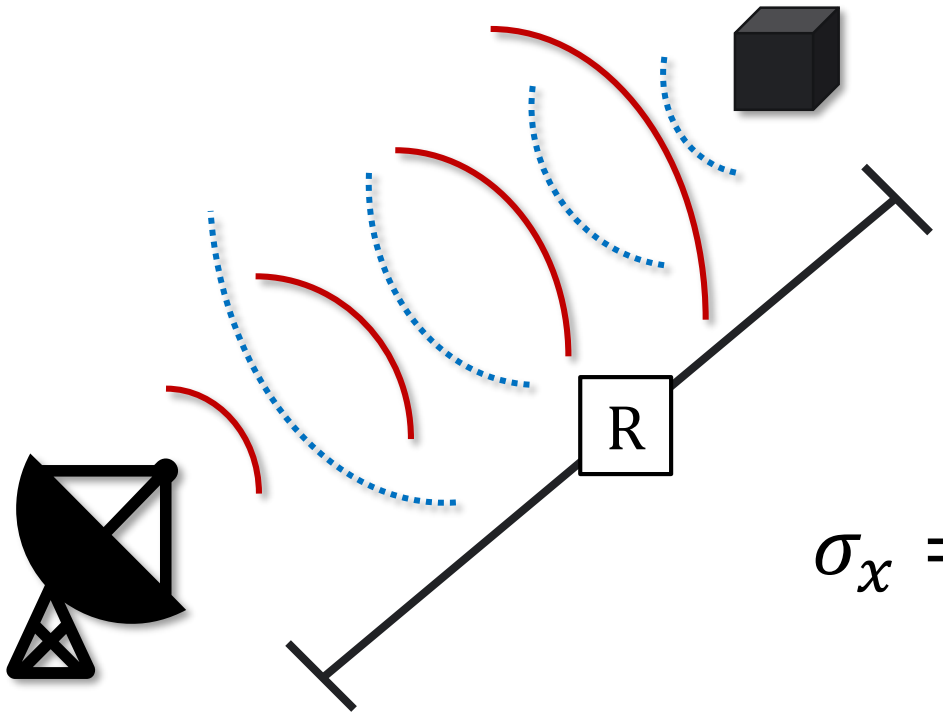
Small sat tracking methods & constraints

Method	Constraints
Transponders	Heavy, needs power, finite lifetime
Optical Beacons	Needs power, finite lifetime
Retro Reflectors	Moderate weight, blocks sensors, needs own area
Van Atta Arrays	Minimum size, blocks sensors, needs own area

Optimal solution requirements

- **Passive (no power)**
- **Little/no sensor blockage**
- **Dual use of aperture**
- **Minimal additional weight**

Radar as a solution: 1



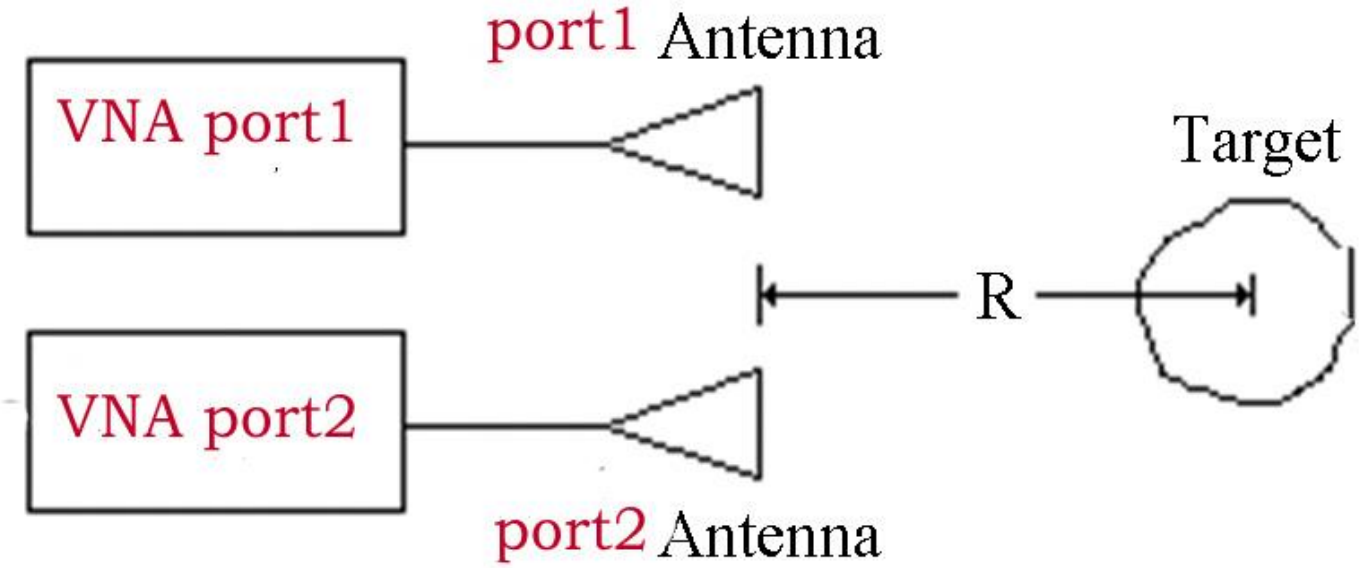
$$P_{RX_A} = P_{TX} G^2 \left(\frac{\lambda}{4\pi R}\right)^2 \frac{\sigma_A}{4\pi R^2}$$

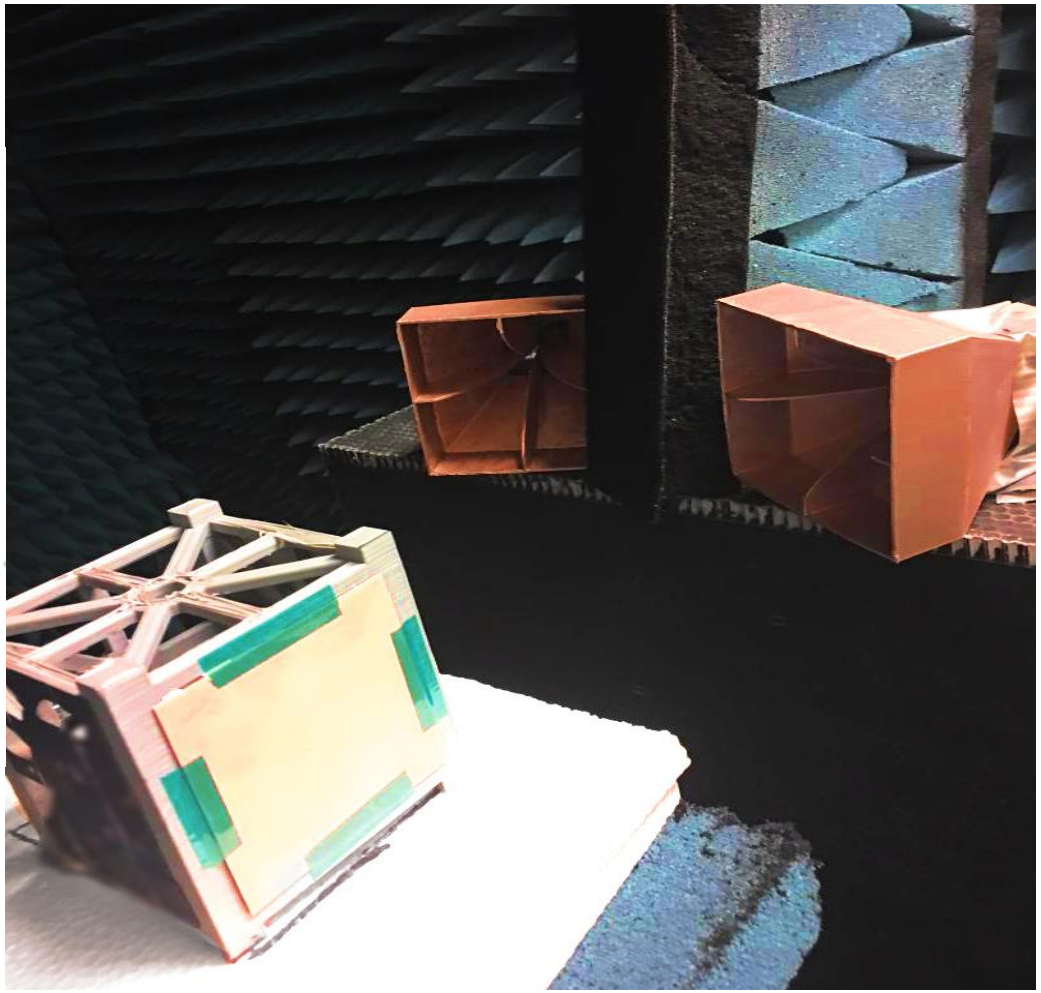
$$\frac{P_{RX_A}}{P_{RX_B}} = \frac{\sigma_A}{\sigma_B}$$

$$\sigma_x = cross\ sec \times directivity \times reflectivity$$

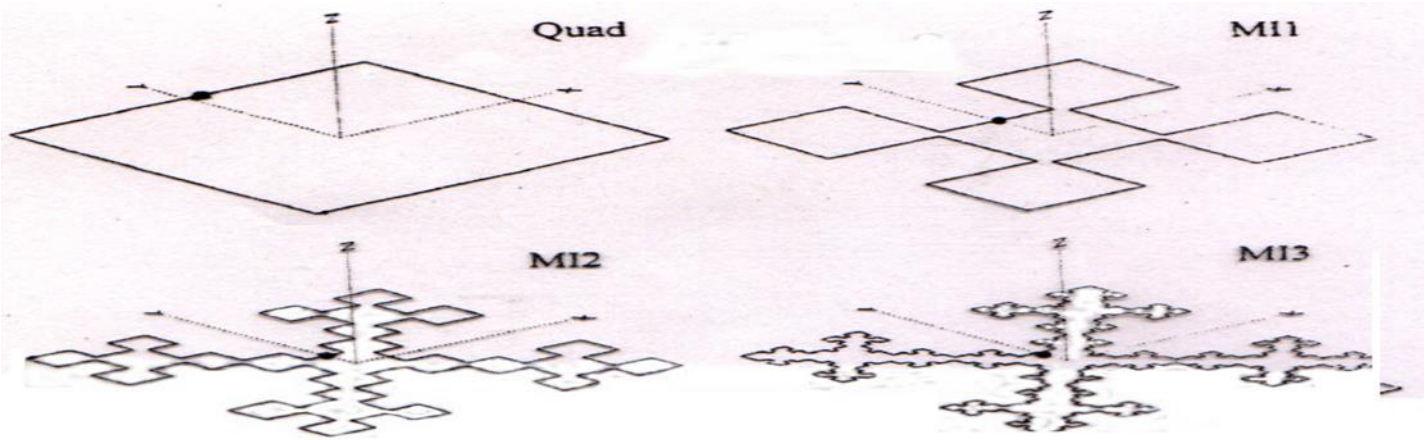
<u>Takeaway:</u> Use differential measurement to get RCS

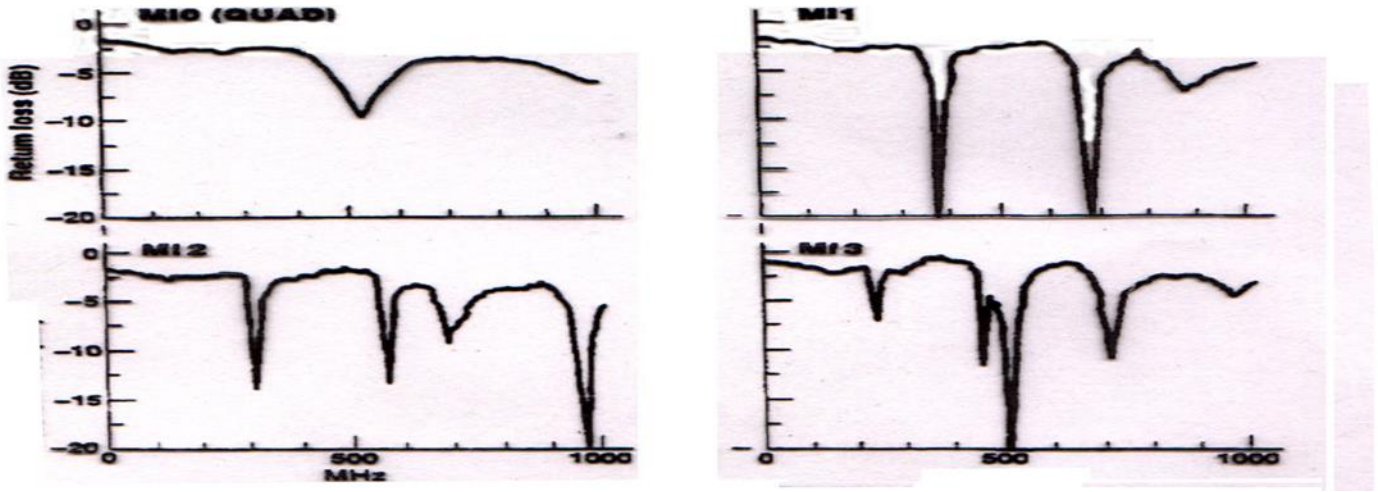
Radar as a solution: 2

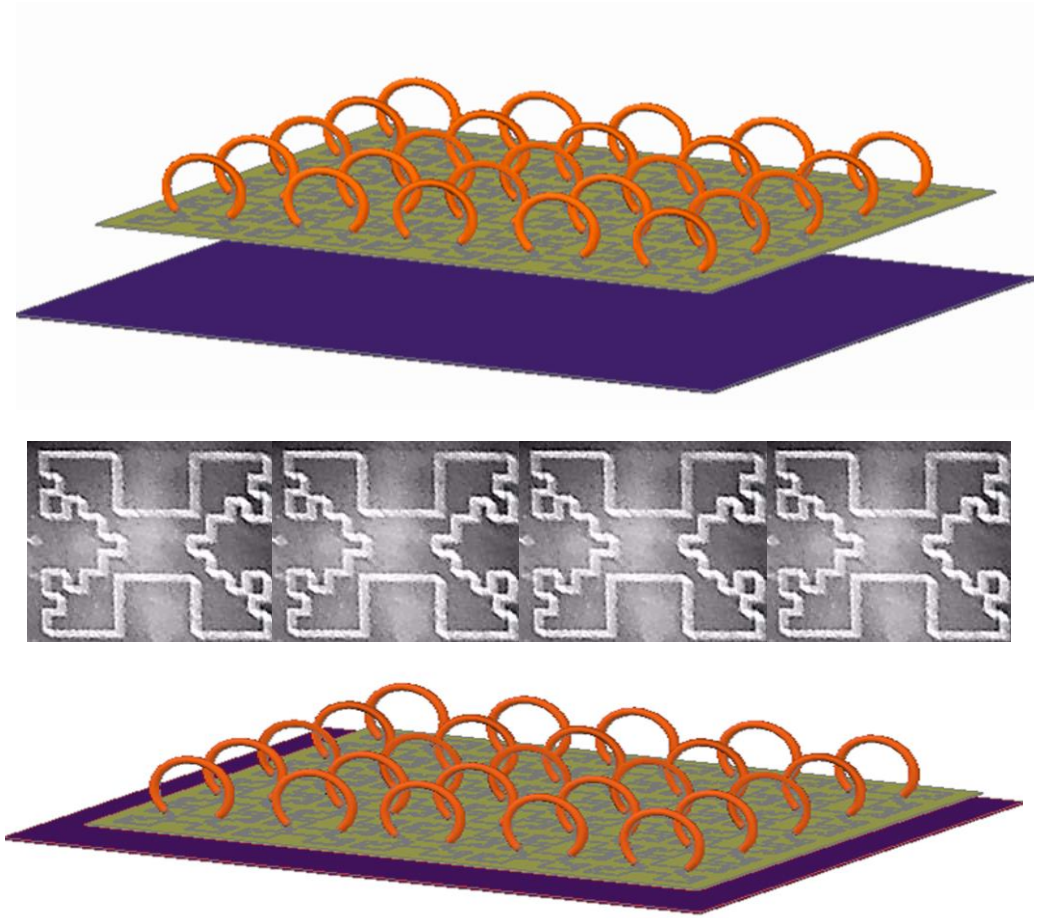




Fractals & fractal metamaterials



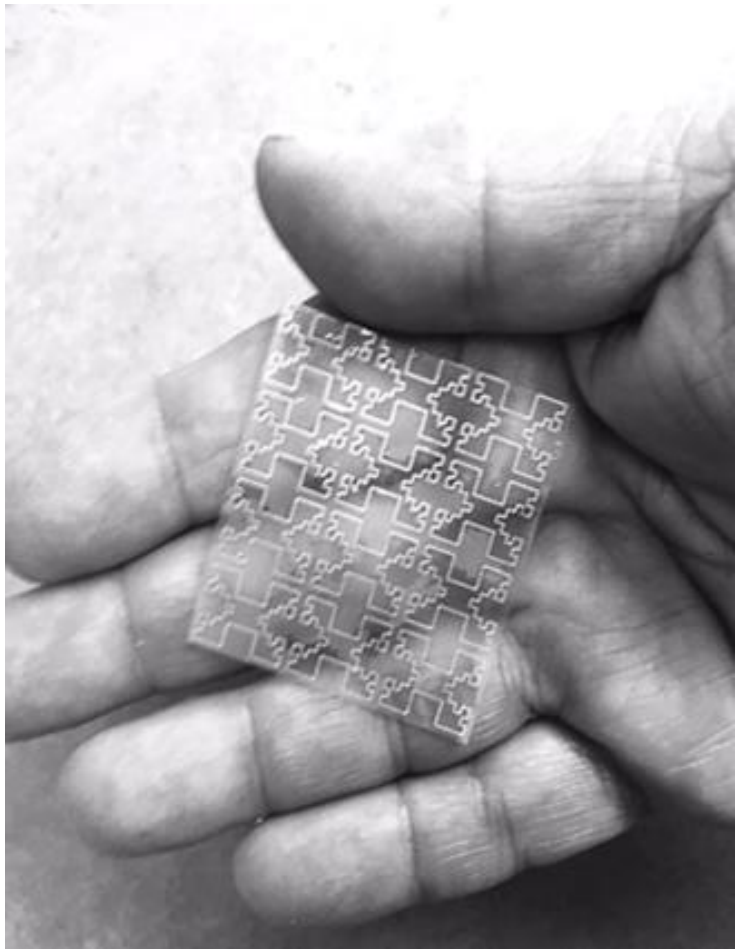


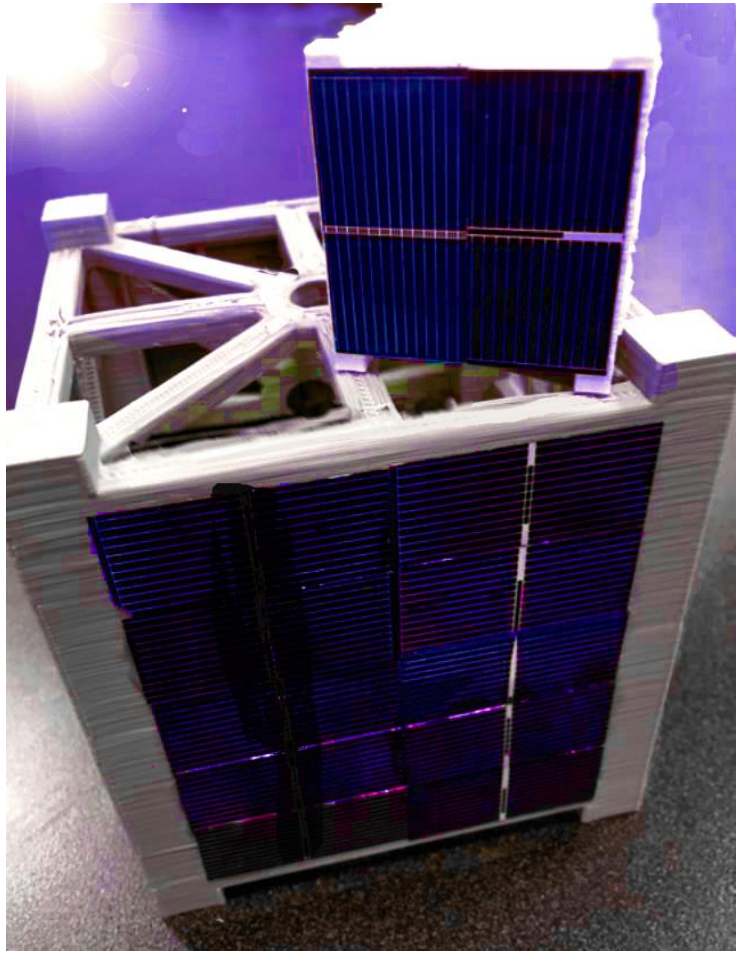


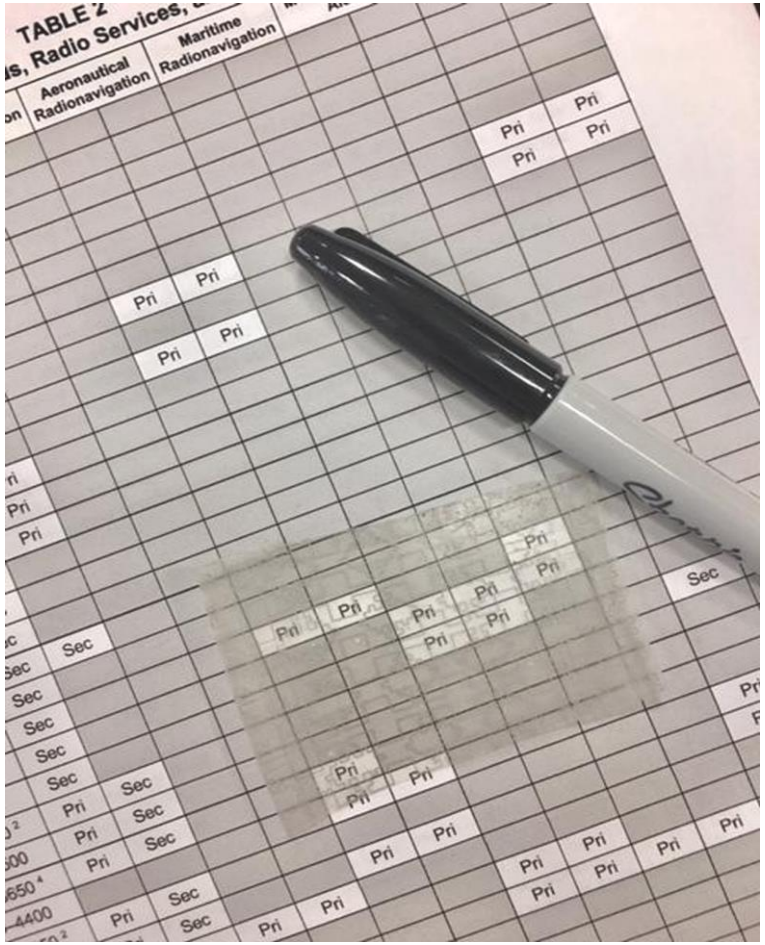
OBJECTIVES

- Use **Fractal Metamaterials** to create paper thin, super-light **"RADARSKINS"**™
- Provide a viable **RCS improvement at S-Band** for tracking a 1U CubeSat
- Enhance RCS by **at least 3dB** = **'Superscatterer'**
- Make the Fractal Metamaterials **optically transparent**
- Allow for the Fractal Metamaterial to **'layer over' solar cells, sensors**
- Show path for **'encoding'** based on **RCS spectral signature**

Fractal Metamaterial => Superscatterer
Dual use aperture with solar cells

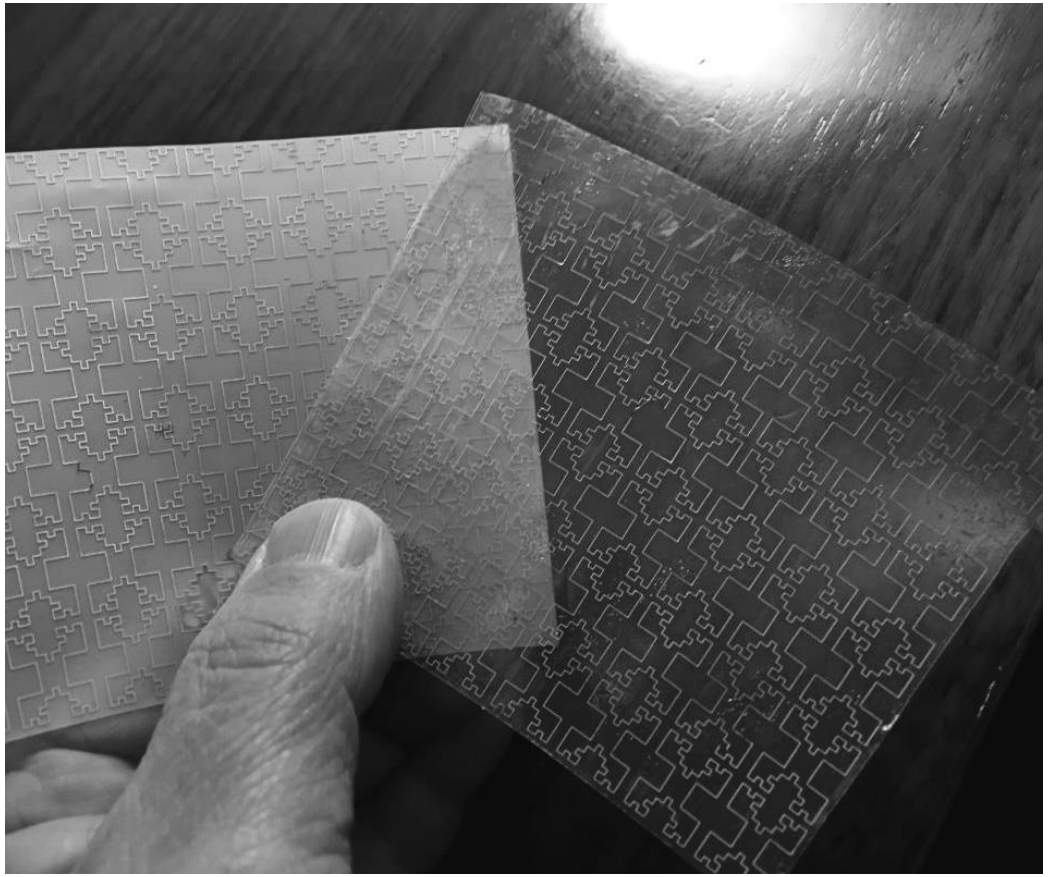






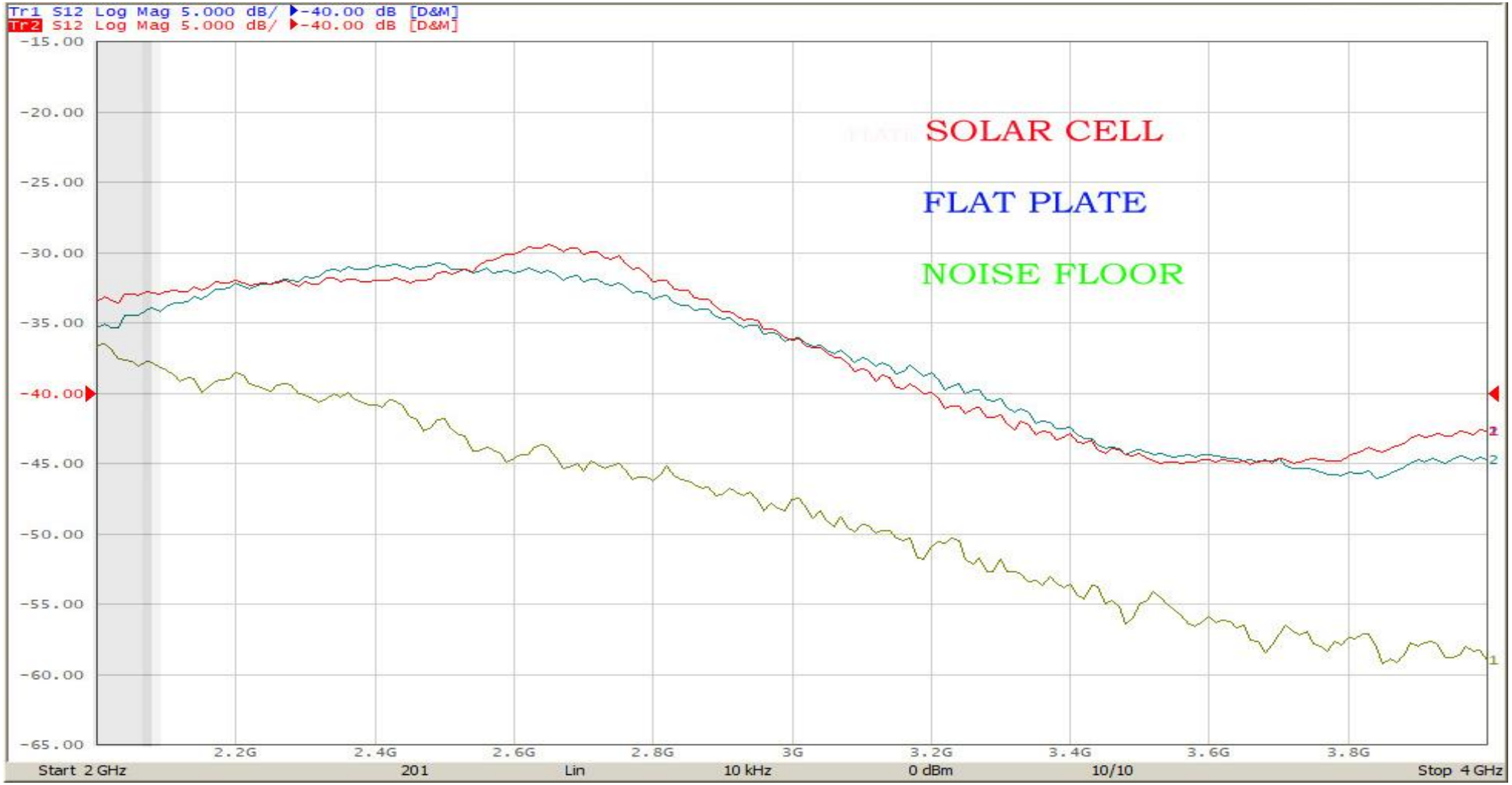
MEASUREMENTS : 1U CUBESAT

- Size: approximately 75 x 80 x 0.6 mm
- Weight: < 5 grams
- Dielectric constant : 3.5
- Polyester with coating; made TRANSPARENT
- Mounted flat on solar cell panel
- Transition from Rayleigh to Mie scattering

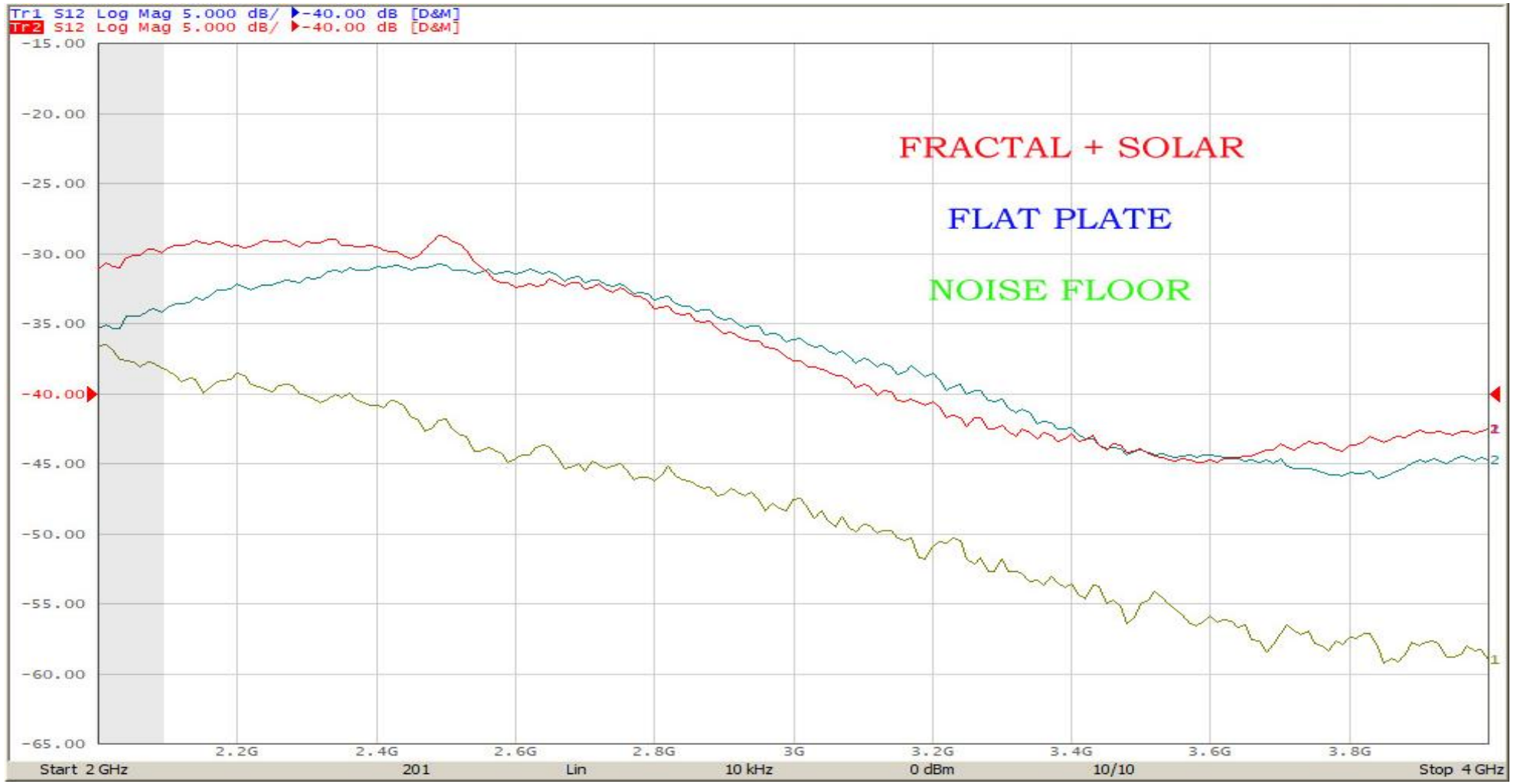


- Comparisons to flat panel; solar cell; 1 & 2 layer fractal superscatterer

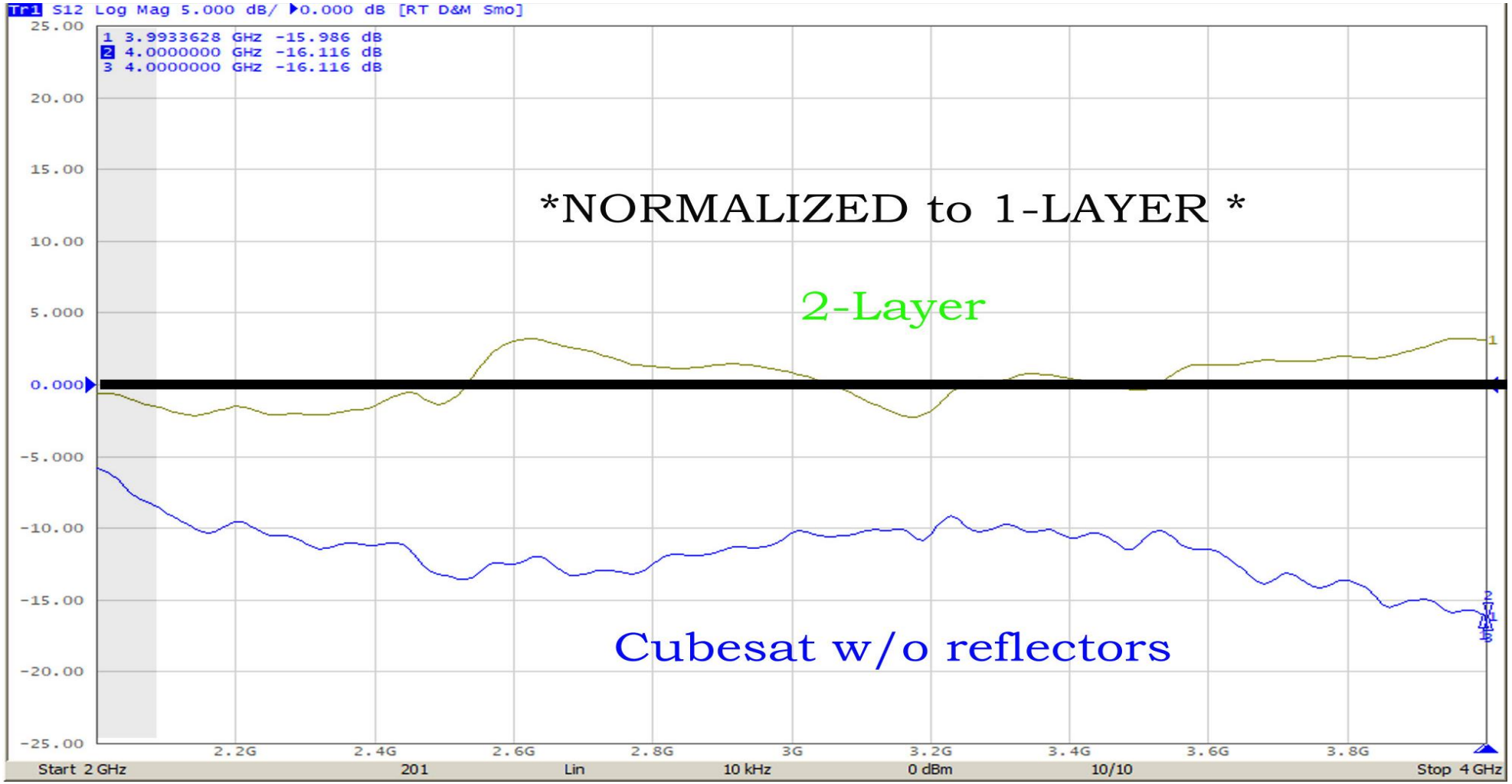
Data: monostatic, on-bore (1/2)



Data: monostatic, on-bore (2/2)



Data: 2-layer fractal metamaterial and Cubesat Skeleton



Data: Results summary

Frequency (GHz)	Scattering Layer	RCS Δ (dB) vs. Flat Plate	Polarization
2.1	1 Layer Fractal MM + SC	4.5	Unpolarized
	2 Layer Fractal MM + SC	2.5	
	Solar Cells Alone	1.0	
2.55	1 Layer Fractal MM + SC	1.0	
	2 Layer Fractal MM + SC	3.5	
	Solar Cells Alone	0.0	
3.9	1 Layer Fractal MM + SC	1.5	
	2 Layer Fractal MM + SC	4.5	
	Solar Cells Alone	1.5	

MOVING AHEAD

- Fractal metamaterials will be **optimized for S-Band RCS**– expect **another 3dB improvement**,
  - ❑ Possible 10dB + RCS increase over conventional <1U CubeSat surfaces
- Based on customer feedback, testing and improvement of **layer transparency for sensors**
- Multilayer fractal metamaterial boards will be used to **encode moderate-'Q' RCS features** for **unique ID** of a CubeSat
- Technology is **patented and patent pending**
- Anticipating an experimental **in-orbit host by 2021/2022**
- **Custom products** under RADARSKINS™ trademark
  - ❑ Customized development for interested customers starting in 2019

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